FUZZY TEMPERATURE COMPENSATION SCHEME FOR HOT WIRE MASS AIRFLOW SENSOR

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LIST OF SYMBOLS

$\lvert\overline{U}\rvert$	Magnitude of the velocity vector
μ_A	Membership function
A_w	Cross-sectional area of the wire
c_w	Specific heat of the wire material
d_w	Wire diameter
h	Coefficient of convective heat transfer
I	Heating current
k_w	Thermal conductivity of air evaluated at subscript temperature
N_i	Number of linguistic values per variable
Q_e	Electric power
Q_T	Out-flowing thermal power
r	Radius of wire
R_a	Heater resistance at reference temperature T_a (ambient)
R_w	Wire resistance
s	Spacing between the pulsed wire and the sensor wire
t	Time
T_a	Temperature of the fluid
t_c	Time of flight
T_w	Wire temperature
V	Voltage drop
v	Velocity
V_{50^oC}	Voltage measured at standard temperature

V_{Ti}	Voltage measured at the temperature T_i
α	Temperature-resistance coefficient of wire material
Δt	Temperature constant degree of difference
η	Temperature recovery factor
ρ_{ref}	Density of the reference wire material
ρ_w	Density of the wire material
σ	Stefan-Boltzmann constant
χ_w	Resistivity of the wire material
Ψ	Angle between the direction normal to the plane of the probe and the instantaneous velocity vector

LIST OF ABBREVIATIONS

CCA	Constant Current Anemometer
COG	Centre of Gravity
CTA	Constant Temperature Anemometer
CTD	Constant-Temperature-Difference
DAC	Digital to Analog Converter
DAQ	Data Acquisition
ECU	Electronic Control Unit
FIS	Fuzzy Inference System
FLC	Fuzzy Logic Controller
FOM	First of Maxima
FTCS	Fuzzy Temperature Compensation Scheme
LOM	Last of Maxima
MAF	Mass Air Flow
MF	Membership Function
MOM	Middle of Maximum
TCR	Temperature Coefficient of Resistance

ABSTRACT

Thermal flow measuring technology has come a long way since the introduction of thermocouple technology and early hot wire anemometers. Thermal technologies depend on heat transfer and traditionally operate on differential temperature measurements between two temperature sensitive materials to generate a signal directly proportional to the temperature differential and mass flow rate. In this thesis, the development of an open-loop Fuzzy Temperature Compensation Scheme (FTCS) for Hot Wire Mass Air Flow (MAF) Sensor is presented. The FTCS for Hot Wire MAF Sensor is used in automotive application to measure the volume and density of air entering the engine at any given time. The Electronic Control Unit (ECU) uses this information in conjunction with input from other sensors to calculate the correct amount of fuel to deliver to the engine and also used indirectly to help calculate desired ignition timing and transmission operating strategies. This FTCS used to compensate the error occurred for the Hot Wire MAF Sensor measurement caused by the temperature variation in the air. The data collection for Hot Wire MAF Sensor inaccuracy analysis is done using NI PCI 6251 DAQ, NI Elvis Board and LABVIEW software. Based on the collected data, the absolute error and percentage error for the sensor output voltage have been calculated compared to the output voltage for the standard temperature value. Then, based on the offset error, six rules for Fuzzy Inference System (FIS) have been developed. The Sugeno type FIS is used for the FTCS design. In order to verify the performance of the proposed Hot Wire MAF Sensor temperature compensation scheme, first a simulation model is developed using Matlab/Simulink. The effectiveness of the proposed fuzzy compensation scheme is verified at different temperature variations compared with Radial Basis Function Neural Network (RBFNN) Temperature Compensation Scheme. Then, based on the Matlab/Simulink simulation, the FTCS has been implemented in real-time using Digital Signal Controllers, dsPIC30F4013 with the Programming C Language. In this regard, a performance comparison of the output voltage of the Hot Wire MAF Sensor after compensated using FTCS, RBFNN Temperature Compensation Scheme and without compensates is provided. These comparison results demonstrate the better improvement for the Hot Wire MAF Sensor measurement accuracy with the estimation percentage error after compensation is only within 0.8451 % of full-scale value.

ABSTRAK

Teknologi pengukuran aliran haba telah wujud sejak pengenalan kepada teknologi termogandingan dan anemometers dawai panas diperingkat awal. Teknologi haba bergantung kepada pemindahan haba dan secara tradisional beroperasi pada perbezaan pengukuran suhu antara dua bahan sensitif suhu untuk menjana isyarat yang berkadar terus dengan perbezaan suhu dan kadar aliran jisim. Dalam tesis ini, pembangunan Skim Pampasan Suhu Fuzzy gelung terbuka(FTCS) untuk Sensor Wayar Panas Aliran Jisim Udara, Hot Wire Mass Air Flow (MAF) Sensor dibentangkan. FTCS untuk Sensor Wayar Panas Aliran Jisim Udara digunakan dalam aplikasi automotif untuk mengukur isipadu dan ketumpatan udara memasuki enjin pada bila-bila masa tertentu. Unit Kawalan Elektronik (ECU) menggunakan maklumat ini bersama-sama dengan input daripada sensor lain untuk mengira jumlah bahan api yang betul untuk dialirkan kepada enjin dan juga digunakan secara tidak langsung untuk membantu mengira pemasaan pencucuhan yang diingini dan strategi operasi penghantaran. FTCS yang digunakan ini adalah untuk membaiki ketidaktepatan pengukuran yang berlaku dalam Sensor Wayar Panas Aliran Jisim Udara yang disebabkan oleh perubahan suhu di udara. Pengumpulan data untuk analisis ketidaktepatan pengukuran Sensor Wayar Panas Aliran Jisim Udara dilakukan menggunakan NI PCI6251 DAQ, NI Elvis Board dan perisian LABVIEW. Berdasarkan data yang dikumpul, ralat mutlak dan ralat peratusan bagi voltan output sensor telah dikira berbanding dengan voltan output bagi nilai suhu standard. Kemudian, berdasarkan kesilapan pengukuran, enam kaedah-kaedah bagi Sistem Inferensi Fuzzy (FIS) telah dibangunkan. FIS jenis Sugeno digunakan untuk reka bentuk FTCS. Untuk mengesahkan prestasi skim pampasan suhu Sensor Wayar Panas Aliran Jisim Udara yang dicadangkan, satu model simulasi dibangunkan menggunakanMatlab/Simulink terlebih dahulu. Keberkesanan skim pampasan Fuzzy yang dicadangkan disahkan dalam simulasi dan dibandingkan dengan skim pampasan menggunakan Fungsi Asas Radial Neural Network (RBFNN) dalam variasi suhu yang berbeza. Kemudian, berdasarkan simulasi Matlab/Simulink, FTCS telah dilaksanakan dalam masa nyata menggunakan Pengawal Isyarat Digital, dsPIC30F4013 dengan Pengaturcaraan C. Dalam hal ini, perbandingan prestasi voltan output Sensor Wayar Panas Aliran Jisim Udara selepas pampasan menggunakan FTCS, Skim Pampasan Suhu RBFNN dan tanpa mengkompensasi disediakan. Keputusan perbandingan menunjukkan peningkatan yang lebih baik untuk ketepatan pengukuran Sensor Wayar Panas Aliran Jisim Udara dengan kesilapan anggaran peratusan selepas pampasan hanyalah 0.8451% daripada nilai skala penuh.

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